CLEANING POLISH ETCH COMPOSITION AND PROCESS FOR A SUPERFINISHED SURFACE OF A SUBSTRATE

Field of the Invention

The present invention relates in general to a cleaning polish etch composition and process for treating a superfinished surface of a substrate. More particularly, the present invention relates to a cleaning polish etch composition and process for removing superfinish polish slurry debris from a superfinished surface of a substrate, such as a disk substrate for a data storage disk or a head wafer from which transducer heads are to be fabricated.

Background

A typical data storage device includes a medium for storing data, typically in magnetic, magneto-optical or optical form, and a transducer used to write and read data respectively to and from the medium. A disk drive data storage device, for example, includes one or more data storage disks coaxially mounted on a hub of a spindle motor. The spindle motor rotates the data storage disks at speeds typically on the order of several thousand or more revolutions-per-minute. Digital information, representing various types of data, is typically written to and read from the data storage disks by one or more transducers, or read/write heads, which are mounted to an actuator assembly and passed over the surface of the rapidly rotating disks.

In a typical magnetic disk drive, for example, data is stored on a magnetic layer coated on a disk substrate. Several characteristics of disk substrates significantly affect the areal density of a disk drive. One such characteristic that significantly affects the areal density of a disk drive is the uniformity of the surface of the disk substrate, i.e., the absence of substrate surface defects. It is generally recognized that minimizing the flyheight, i.e., the clearance distance between the read/write head and the surface of a data storage disk, generally provides for increased areal densities. It is also recognized in the art, however, that the smoothness of the surface of a data storage disk becomes a critical factor and design constraint when attempting to minimize the

flyheight. A significant decrease in flyheight provided by the use of data storage disks having highly uniform recording surfaces can advantageously result in increased transducer readback sensitivity and increased areal density of the disk drive. The uniformity of disk substrate surfaces affects the uniformity of the recording surfaces because the layers sputtered onto the disk substrate, such as the magnetic layer, replicate any irregular surface morphology of the disk substrate.

Conventionally, disk substrates have been based upon aluminum, such as NiP coated Al/Mg alloy substrates. Coating the aluminum magnesium alloy with a nickel-phosphorus plate provides a harder exterior surface which allows the disk substrate to be polished and superfinished. A conventional superfinishing process and slurry is described in U.S. Patent No. 6,236,542 to Hartog et al., which is assigned to the assignee of the present application. Typically, the Al/Mg-NiP substrate is superfinished to a smooth finish with a colloidal slurry, e.g., a pH adjusted aqueous slurry containing colloidal silica and/or colloidal alumina particles and an etching agent such as aluminum nitrate, prior to sputtering with thin film magnetic coatings. The colloidal alumina and silica slurries are then cleaned from the substrate by the general cleaning mechanisms of mechanical scrubbing, dispersion and etching. Surfactants and pH are generally used for dispersion cleaning, where the surfactant and pH act to separate the slurry particles from each other and from the substrate. Etching is generally accomplished by acids and acid soaps that erode or dissolve the substrate material beneath embedded slurry particles (under-cut) to release them from the substrate. Typical acids in use for NiP plated Al-based substrates include, for example, straight phosphoric acid, nitric acid, hydrofluoric acid-based soaps and phosphoric acid-based soaps. The straight acids generally have a pH less than 1 and the soaps generally have pH's above 1.

After cleaning, the substrates are sputtered with a series of layers, e.g., a chrome underlayer, a magnetic layer and a carbon protection layer. If residual slurry particles are left on the substrate or if there is galling to the relatively soft NiP layer, the sputtered layers replicate the

irregular surface morphology, creating a bumpy surface on the finished disk. When the read/write head glides over the surface, it crashes into bumps created by the residual particles and/or damage that is higher than the glide clearance. This is known as a glide defect, which can ultimately cause disk drive failure. These bumps further cause magnetic defects, corrosion and decreased disk life. Thus, the residual slurry particles and/or damage needs to be removed from the superfinished substrate surface so that the substrate is as smooth as possible.

Unfortunately, aluminum-based substrates have relatively low specific stiffness, as well as relatively low impact and dent resistance. For example, the relatively low specific stiffness of the Al/Mg-NiP substrates (typically 3.8 Mpsi/gm/cc) makes this type of disk substrate susceptible to environmental forces which create disk flutter and vibration and which may cause the read/write head to impact and dent the disk substrate surface.

More recently, glass substrates have been used for disk drives in portable devices, such as laptop computers. Glass substrates have a higher impact and dent resistance than aluminum-based substrates, which is important in portable devices where the unit is subject to being bumped, dropped and banged around, causing the read/write head to bang on the disk substrate surface. Moreover, the specific stiffness of glass or glass-ceramic substrates (typically ≤ 6 or 7 Mpsi/gm/cc) is typically higher than that of aluminum-based substrates.

An additional benefit of glass is that it is easier to polish to and maintain as a smooth surface finish (as compared to NiP) than aluminum-based substrates. A smoother substrate allows the read/write head to fly closer to the disk, which produces a higher density recording. Glide height for some computer disk drives is on the order of 20 nanometers (about 200 Å) and less, which is an extremely small interface distance. Thus, the fact that glass substrates can be polished to smoother finishes makes an industry shift from Al-based substrates to glass substrates desirable, not only for disk drives used in portable devices, but for disk drives used in stationary devices as well.

The surface uniformity of glass substrates can still present a problem, however, especially for low glide heights (typically $\leq$ 20 nanometers) and near contact recording. Just as with aluminum-based substrates, the surface of the glass substrate needs to be polished and superfinished with a slurry to provide an atomically smooth surface prior to sputtering. Such a conventional superfinishing polish process and slurry is also described in the above referenced U.S. Patent No. 6,236,542 to Hartog et al. Typically, the glass substrate is superfinished to a smooth finish with a colloidal slurry, e.g., a pH adjusted aqueous slurry containing colloidal silica and/or colloidal alumina particles and an etching agent such as cerium sulfate, prior to sputtering with thin film magnetic coatings.

In this conventional superfinishing polish process colloidal silica particles attach to the surface being polished not only by the usual London dispersion forces, van der Waals forces and hydrogen bonding, but unlike NiP, also by molecular bonding even though the slurry has the usual stabilizing agents used in the colloidal silica to prevent the silica particles from sticking to each other (interparticle siloxane bonding), charge repulsion and/or steric stabilizers. Standard methods of scrubbing with soaps using polyvinyl alcohol (PVA) pads, ultrasonics or megasonics will not remove any significant percentage of such molecular bonded silica particles. Just as with aluminum-based substrates, if these particles are left in place on the glass substrate, glide defects occur that can ultimately cause disk drive failure. These glide defects further cause magnetic defects, corrosion and decreased disk life.

An apparent solution to this problem would be to use stronger acid or base solutions than the cleaning soap, to etch the glass substrate or undercut the slurry particles similar to what can be done to remove hard alpha alumina from Al/Mg-NiP substrates after non-superfinish polish slurries. The surface finish of glass and NiP substrates are, however, damaged by such a technique by surface topography change such as pitting and chemical composition changes. Glass has low resistance to acid etching and overly aggressive acid solutions, such as hydrofluoric acid and caustic etching at high pH's and temperatures. Damage and compositional

change to the superfinished glass surface will adversely affect the morphology of layers deposited by subsequent sputtering processes and can cause magnetic, glide and corrosion failures. Nonetheless, etching by itself (followed with PVA scrub, ultrasonics or megasonics) is what has been done to remove slurry particles from Al/Mg-NiP or glass substrates. With the less than 20 nm glide heights now in use, however, an improved debris removal mechanism is needed to ensure 100% surface cleaning of particles that small (i.e., the lower the glide height, the smaller the particles needing to be removed, and thus the more difficult they are to remove) while maintaining the surface finish (i.e., the glass substrate can be damaged by using only chemical etch due to the low resistance of the glass material to acid etching or overly aggressive caustic etch solutions).

Another apparent solution to this problem would be to micropolish the surface of the glass substrate, e.g., by using a burnishing head, to remove the glide defects prior to applying the sputtered layers, such as a magnetic layer and a carbon protection layer. However, glass substrates cannot be effectively micropolished because applying the burnishing head to the glass surface can cause micro-fracturing rather than just a surface levelling. The micro-fractured site becomes a risk for corrosion and/or a growing defect.

If the market trend toward glass substrates in disk drives is to succeed, a mechanism other than the cleaning techniques of etching or micropolishing is required for removing slurry particles which adhere to the surfaces of the substrates that are superfinished using a slurry. Preferably, such a contamination removal mechanism would not adversely alter the finish of the substrate or surface stability to corrosion.

Summary of the Invention

An object of the present invention is to provide an enhanced contamination removal mechanism for substrates that are superfinished using a slurry.

Another object of the present invention is to provide an enhanced contamination removal mechanism that does not adversely alter the superfinish of the substrate or surface stability to corrosion for substrates that are superfinished using a slurry.

These and other objects of the present invention are achieved by a cleaning polish etch composition and process for removing slurry particles which adhere to the surfaces of the substrates that are superfinished using a slurry. The cleaning polish etch composition comprises a carrying fluid and etchant for etching the substrate and/or the attached slurry particles. The cleaning polish etch composition is applied to the surface of the substrate while a pad mechanically rubs the surface to etch the substrate under polish conditions thereby maintaining the superfinish surface while removing the superfinish polish slurry debris by etching and dilution. Subsequent cleaning with standard soap solutions removes substantially all remaining contamination from the surface of the substrate.

In an exemplary embodiment, the cleaning polish etch composition and process is used to remove slurry particles which adhered to the surfaces of a glass disk substrate that was superfinished using a conventional superfinishing slurry. In this exemplary embodiment, the cleaning polish etch composition and process produced a glass disk substrate having a surface roughness of less than 2 Å, with substantially no surface contamination as seen by atomic force microscope (AFM) after standard soap cleaning steps. A data storage disk for use in a data storage device may be provided by applying a recording layer over the superfinished surface of the glass disk substrate after the standard soap cleaning steps.

In another exemplary embodiment, the cleaning polish etch composition and process is used to remove slurry particles which adhered to the surfaces of a Sendust head wafer that was superfinished using a conventional wafer superfinishing slurry. In this exemplary embodiment, the cleaning polish etch composition and process produced a Sendust head wafer having substantially no surface contamination as seen by atomic force microscope (AFM) after standard

soap cleaning steps. The Sendust head wafer may then be further processed using conventional fabrication steps to provide a plurality of transducer heads for use in data storage devices.

Brief Description of the Drawings

The present invention together with the above and other objects and advantages can best be understood from the following detailed description of the embodiments of the invention illustrated in the drawings, wherein like reference numerals denote like elements.

FIG. 1 is a top view of a data storage device with its upper housing cover removed and employing one or more transducer heads and/or data storage disks that have been treated using a cleaning polish etch composition and process in accordance with the present invention.

FIG. 2 is a side plan view of a data storage device comprising a plurality of transducer heads and/or data storage disks that have been treated using a cleaning polish etch composition and process in accordance with the present invention.

FIG. 3 is a perspective view of a disk substrate that has been that have been treated using a cleaning polish etch composition and process in accordance with the present invention.

FIG. 4 is a cross-sectional view of a multi-layer disk substrate that have been treated using a cleaning polish etch composition and process in accordance with the present invention.

FIG. 5 shows how the polishing pads of the preferred embodiment operate to generate polishing action.

FIG. 6 shows how the disk substrate carriers of the preferred embodiment operate in relation to polishing pads to generate polishing action.

FIG. 7 shows how a cleaning polish etch solution is introduced onto disk substrates in accordance with the present invention.

Detailed Description of the Preferred Embodiments

Overview

Many types of substrates (e.g., a disk substrate for a data storage disk, a head wafer from which transducer heads are to be fabricated, a semiconductor wafer, a lens, a mirror, etc.) need to be polished and superfinished with a slurry to provide an atomically smooth surface. A conventional superfinishing polish process and slurry for use in such applications is described in U.S. Patent No. 6,236,542 to Hartog et al. Typically, the conventional superfinishing polish slurry comprises a carrying fluid, colloidal particles (e.g., colloidal silica or colloidal alumina), and etchant (e.g., metal etchant such as Ce, Zr, Ti, Fe, Sn, Al, Cr, Ni, Mn or Zn) for etching the substrate and/or the attached slurry particles. The conventional colloidal slurry is applied to the surface of the substrate while a pad mechanically rubs the surface.

For example, a glass disk substrate is typically superfinished to a smooth finish with a conventional colloidal slurry, e.g., a pH adjusted aqueous slurry containing colloidal silica and/or colloidal alumina particles and an etching agent such as cerium sulfate, prior to sputtering with thin film magnetic coatings. In the conventional superfinishing polish process, colloidal silica particles attach to the glass surface being polished not only by the usual London dispersion forces, van der Waals forces and hydrogen bonding, but unlike NiP coated Al/Mg alloy substrates, also by molecular bonding even though the slurry has the usual stabilizing agents used in the colloidal silica to prevent the silica particles from sticking to each other (interparticle siloxane bonding), charge repulsion and/or steric stabilizers. Standard methods of scrubbing with soaps using polyvinyl alcohol (PVA) pads, ultrasonics or megasonics will not remove any significant percentage of such molecular bonded silica particles. Just as with aluminum-based substrates, if these particles are left in place on the glass substrate, glide defects occur that can

ultimately cause disk drive failure. These glide defects further cause magnetic defects, corrosion and decreased disk life.

The present invention provides a solution to this problem. The present invention utilizes a cleaning polish etch composition and process for removing slurry particles which adhere to the surfaces of the substrates that are superfinished using a slurry. The cleaning polish etch composition comprises a carrying fluid (e.g., acid, neutral or base solutions) and etchant (e.g., metal etchant such as Ce, Zr, Ti, Fe, Sn, Al, Cr, Ni, Mn or Zn) for etching the substrate and/or the attached slurry particles. The cleaning polish etch composition is applied to the surface of the substrate while a pad mechanically rubs the surface to etch the substrate under polish conditions thereby maintaining the superfinish surface while removing the superfinish polish slurry debris by etching and dilution. That is, the cleaning polish etch process is performed by running the substrate on a polishing pad using a cleaning polish etch solution instead of a slurry, i.e., there are no slurry particles in the cleaning polish etch solution. Subsequent cleaning with standard soap solutions removes substantially all remaining contamination from the surface of the substrate.

In an exemplary embodiment, the cleaning polish etch composition and process is used to remove slurry particles which adhered to the surfaces of a glass disk substrate that was superfinished using a conventional superfinishing slurry. In this exemplary embodiment, the cleaning polish etch composition and process produced a glass disk substrate having a surface roughness of less than 2 Å, with substantially no surface contamination as seen by atomic force microscope (AFM) after standard soap cleaning steps. A data storage disk for use in a data storage device may be provided by applying a recording layer over the superfinished surface of the glass disk substrate after the standard soap cleaning steps.

In another exemplary embodiment, the cleaning polish etch composition and process is used to remove slurry particles which adhered to the surfaces of a Sendust head wafer that was

superfinished using a conventional wafer superfinishing slurry, e.g., a straight colloid alumina or colloidal silica (without etchant). In this exemplary embodiment, the cleaning polish etch composition and process produced a Sendust head wafer having substantially no surface contamination as seen by atomic force microscope (AFM) after standard soap cleaning steps. The Sendust head wafer may then be further processed using conventional fabrication steps to provide a plurality of transducer heads for use in data storage devices.

The cleaning polish etch composition and process of the present invention can unfortunately add to equipment and handling costs. Nonetheless, without the polish etch composition and process of the present invention, the surface of a glass substrate, for example, can be damaged by using only chemical etch (i.e., stronger acid or base solutions than cleaning soaps to etch the substrate or undercut the slurry particles) due to the low resistance of the glass material to acid etching or overly aggressive caustic etch solutions. Etching by itself (followed with PVA scrub, ultrasonics or megasonics) is what has been done to remove slurry particles from Al/Mg-NiP or glass substrates. With the less than 20 nm glide heights now in use, however, the cleaning polish etch composition and process of the present invention is needed to ensure 100% surface cleaning of particles that small (i.e., the lower the glide height, the smaller the particles needing to be removed, and thus the more difficult they are to remove) while maintaining the surface finish (i.e., the glass substrate can be damaged by using only chemical etch due to the low resistance of the glass material to acid etching or overly aggressive caustic etch solutions).

The Data Storage Device

Referring now to the drawings, and more particularly to FIGS. 1 and 2, there is shown a magnetic data storage device 20 utilizing transducer heads and/or magnetic disks with disk substrates that have been treated using a cleaning polish etch composition and process in accordance with embodiments of the present invention. Magnetic data storage device 20 is shown in FIG. 1 with its cover (not shown) removed from a base 22 of a housing 21. As best

seen in FIG. 2, the magnetic data storage device 20 includes one or more rigid data storage disks 24 that are rotated by a spindle motor 26. The rigid data storage disks 24 are constructed with a disk substrate upon which a recording layer is formed. In an exemplary construction, a magnetizable recording layer is formed on a glass disk substrate. Alternatively, an optical recording layer or a magneto-optical recording layer may be formed on the disk substrate in lieu of the magnetizable recording layer.

Referring back to FIG. 1, an actuator assembly 37 typically includes a plurality of interleaved actuator arms 30, with each arm having one or more suspensions 28 and transducer heads 27 mounted on airbearing sliders 29. The transducer heads 27 typically include components both for reading and writing information to and from the data storage disks 24. Each transducer head 27 may be, for example, a magnetoresistive (MR) head having a write element and a MR read element. Alternatively, each transducer head may be an inductive head having a combined read/write element or separate read and write elements, or an optical head having separate or combined read and write elements. The actuator assembly 37 includes a coil assembly 36 which cooperates with a permanent magnet structure 38 to operate as an actuator voice coil motor (VCM) 39 responsive to control signals produced by a controller 58. The controller 58 preferably includes control circuitry that coordinates the transfer of data to and from the data storage disks 24, and cooperates with the VCM 39 to move the actuator arms 30 and suspensions 28, to position transducer heads 27 to prescribed track 50 and sector 52 locations when reading and writing data from and to the data storage disks 24.

The Disk Substrate

FIG. 3 shows a disk substrate that has been treated using a cleaning polish etch composition and process in accordance with a first embodiment of the present invention. Disk substrate 300, which has a disk substrate surface 302, is preferably a material having a relatively high specific stiffness (e.g., ≥3.8 Mpsi/gm/cc) such as a glass, glass-ceramic, ceramic, glass composite, metal or metal composite. More preferably, the disk substrate 300 is a glass, glass-

ceramic or ceramic. Most preferably, the disk substrate 300 is an aluminosilicate glass. A common disk substrate material, e.g., aluminosilicate glass, has been chosen for the preferred embodiment to best illustrate the teachings of the present invention. However, it should be understood that the present invention is not limited to just aluminosilicate glass.

Any number of materials may be used for the disk substrate in accordance with the invention. Examples of materials that may be used as the disk substrate include alumina, sapphire, silicon carbide, boron carbide, metal matrix composites, and aluminum/boron carbide composites. Other examples of materials that may be used as the disk substrate include carbides, nitrides, oxides and phosphides or mixtures thereof. Still another example of a material that may be used as the disk substrate is a fiber reinforced composite such as graphite fiber reinforcement.

Metal matrix composites are made by pigmenting a metal, such as aluminum, with a ceramic powder. The mixture is then melted and formed into a disk substrate. The concentration of ceramic powder is balanced to provide optimal physical properties.

Other materials that may be fabricated into composites that may be used for the disk substrate include those such as silicon carbide, sapphire, titanium nitride, boron carbide, boron nitride, carbon, silicon nitride, as well as composites of glass and ceramic.

A representative list of compositions along with their relative specific stiffnesses (Mpsi/gm/cc) that may be used is found in Table 1 below.

TABLE 1

Specific	Material Stiffness
Aluminum	3.8
Aluminosilicate glass	4.9
Lithium silicate glass	5.2
Canasite glass ceramic	4.6
Flint glass ceramic	6.6
Quartz glass	4.9-6.1
Titanium alloy	3.3
Zirconia	5.1
Alumina	14.7
Silicon carbide	15.7-19.5
Beryllium	22.5
Carbon	2.2
Alumina/aluminum composite	5.3
Boron carbide	26.1
Boron carbide/aluminum composite	11.1-21.2

These materials may be used alone or in combination to provide the disk substrate of the appropriate stiffness. Preferably, the disk substrate has a stiffness of at least about 3.8 Mpsi/gm/cc.

Other useful materials for the disk substrate include glass compositions, ceramics, and mixtures thereof. Glass is generally a silicate material having a structure of silicon and oxygen where the silicon atom is tetrahedrally coordinated to surrounding oxygen atoms. Any number of

materials may be used to form glass such as boron oxide, silicon oxide, germanium oxide, aluminum oxide, phosphorous oxide, vanadium oxide, arsenic oxide, antimony oxide, zirconium oxide, titanium oxide, aluminum oxide, thorium oxide, beryllium oxide, cadmium oxide, scandium oxide, lanthanum oxide, yttrium oxide, tin oxide, gallium oxide, indium oxide, lead oxide, magnesium oxide, lithium oxide, zinc oxide, barium oxide, calcium oxide, stronium oxide, sodium oxide, cadmium oxide, potassium oxide, rubidium oxide, mercury oxide, and cesium oxide.

Glass-ceramics may also be used for the disk substrate. Glass-ceramics generally result from the melt formation of glass and ceramic materials by conventional glass manufacturing techniques. Subsequently, the materials are heat cycled to cause crystallization. Typical glass-ceramics are, for example, ß-quartz solid solution, SiO_2; ß-quartz; lithium metasilicate, Li_2O--SiO_2; lithium disilicate, $Li_2 (SiO_2)_2$; ß-spodumene solid solution; anatase, TiO_2; ß-spodumene solid solution; rutile TiO_2; ß-spodumene solid solution; mullite, $3Al_2O_3$--$2SiO_2$; ß-spodumene dorierite, $2MgO$--$2Al_2O_3$ --$5SiO_2$; spinel, MgO--Al_2O_3; MgO-stuffed; ß-quartz; quartz; SiO_2; alpha-quartz solid solution, SiO_2; spinel, MgO--Al_2O_3; enstatite, MgO--SiO_2; fluorphlogopite solid solution, $KMg_3AlSi_3O_{10}F_2$; mullite, $3Al_2O_3$--$2SiO_2$; and $(Ba, Sr, Pb)Nb_2O_6$.

Ceramics are generally comprised of aluminum oxides such as alumina, silicon oxides, zirconium oxides such as zirconia or mixtures thereof. Typical ceramic compositions include aluminum silicate; bismuth calcium strontium copper oxide; cordierite; feldspar, ferrite; lead lanthanum zirconate titanate; lead magnesium nobate (PMN); lead zinc nobate (PZN); lead zirconate titanate; manganese ferrite; mullite; nickel ferrite; strontium hexaferrite; thallium calcium barium copper oxide; triaxial porcelain; yttrium barium copper oxide; yttrium iron oxide; yttrium garnet; and zinc ferrite.

Aluminum-boron-carbide composite may also be used for the disk substrate, preferably with a ratio of aluminum to boron carbide (vol.%) ranging from about 1:99 to 40:60. The

specific stiffness of these materials typically ranges from about 11.1 to 21.2 Mpsi/gm/cc. These disks are commonly referred to as aluminum-boron-carbide composites or AlBC composites.

The disk substrate may be made entirely of one material, or may include a coating layer applied over at least one surface of an inner core. Referring now to FIG. 4, which shows a cross section view of such a multi-layer disk substrate, a disk substrate 400 comprises an inner core 402 and upper and lower coating layers 404. The inner core 402 is preferably made of a material having a relatively high specific stiffness, such as a glass, glass-ceramic, ceramic, glass composite, polymer, polymer composite, metal or metal composite. The coating layers 404 are preferably made of a material having a defect free surface, such as an NiP layer or a glassy carbon layer.

Also, it should be understood that the present invention is not limited to disk substrates that are to be coated with a recording layer. For example, the present invention is equally applicable to disk substrates made entirely of magnetic material.

Transducer Heads

Referring back to FIGS. 1 and 2, transducer heads 27 may be fabricated from a head wafer treated using a cleaning polish etch composition and process in accordance with a second embodiment of the present invention. The head wafer is preferably a material, such as Sendust (iron-silicon-aluminum alloys), Permalloy (iron-base alloys containing about 45-80% nickel), or the like, having desired physical and magnetic properties. A common head wafer material, e.g., Sendust, has been chosen for the preferred embodiment to best illustrate the teachings of the present invention. However, it should be understood that the present invention is not limited to just Sendust.

Superfinishing Polish Process and Slurry

The substrate (e.g., a disk substrate and/or a head wafer from which transducer heads are fabricated) is initially polished and superfinished with a slurry to provide an atomically smooth

surface. Superfinishing polishing slurries, and processes for their use, are well known in the art, and thus not discussed in detail herein. Exemplary superfinishing polish slurries and processes are described in U.S. Patent No. 6,236,542 to Hartog et al, which is incorporated herein by reference. However other superfinishing polish slurries and/or processes may be used. The superfinishing polish slurry typically comprises a carrying fluid, colloidal particles (e.g., colloidal silica or colloidal alumina), and etchant (e.g., metal etchant such as Ce, Zr, Ti, Fe, Sn, Al, Cr, Ni, Mn or Zn) for etching the substrate and/or the attached slurry particles. Acid or base etchant solutions (without metal etchant) may be used as the etchant in lieu of metal etchant. In this case, metal ions from the substrate composition will be present in the colloidal slurry for the superfinishing polish process. The colloidal slurry is applied to the surface of the substrate while a polishing pad attached to a polishing plate mechanically rubs the surface. Preferably, a double-sided polishing machine is used, e.g., a three motor, 9B-5P SpeedFam Double-Sided Polishing Machine made by SpeedFam Corporation. However other conventional polishing machines could also be used. Preferably, the polishing pads are Napcon H7000SPH#2 polishing pads made by Fujibo; however, other polishing pads with similar characteristics could also be used. While pressure is applied axially, an upper plate and a lower polishing plate are rotated in opposite directions. The axial pressure applied should be set to approximately 1-1.5 psi-disk (pounds per square inch of disk area). The lower polishing plate and attached polishing pad should be set to rotate at 60 RPM, while the upper polishing plate and attached polishing pad should be set to rotate at 20 RPM. Additional details regarding superfinishing polish slurries and processes may be obtained by referring to the Hartog et al. patent.

Cleaning Polish Etch Process

An embodiment of the cleaning polish etch process of the present invention is described below with respect to removing superfinish polish slurry debris from disk substrates. The cleaning polish etch process for removing superfinish polish slurry debris from head wafers, i.e., the head wafer embodiment of the present invention, is similar to the disk substrate embodiment. Certain differences do exist, however. Accordingly, differences between the head wafer embodiment and the disk substrate embodiment are pointed out and discussed in detail below. In

other respects, the discussion of the disk substrate embodiment also pertains the head wafer embodiment.

Polishing Machine and Process Parameters

The polishing machine of the preferred embodiment is a three motor, 9B-5P SpeedFam Double-Sided Polishing Machine made by SpeedFam Corporation. However other conventional polishing machines could also be used. The double-sided polishing action of typical double sided polishing machines is shown in FIG. 5. Individual disk substrates are held between polishing pads 510 and 515 by polishing plates 500 and 505. The polishing pads used in the preferred embodiment are Napcon 4600 polishing pads made by Fujibo; however, other polishing pads with similar characteristics could also be used. While pressure is applied axially to shaft 520, polishing plates 500 and 505 are rotated in opposite directions (shown by rotation arrows 530 and 535). The pressure applied to shaft 520 should be set to approximately 0.25 psi-disk (pounds per square inch of disk area). Lower polishing plate 505 and attached polishing pad 515 should be set to rotate at 30 RPM, while upper polishing plate 500 and attached polishing pad 510 should be set to rotate at 60 RPM.

Supply ports, such as supply ports 525, are used in introducing the cleaning polish etch solution onto the disk substrates. As a result of this double-sided polishing action, both the top and bottom sides of the disk substrates are treated simultaneously.

FIG. 6 shows how the disk substrate carriers, such as disk substrate carrier 600, operate in relation to lower polishing pad 515 and upper polishing pad 510. Disk substrate carrier 600 rotates in the same direction as polishing pad 510 (not shown) and in the direction opposite to polishing pad 515 (shown by arrow 535) such that disk substrates, such as disk substrate 400, are polished on both sides.

FIG. 7 shows how cleaning polish etch solution 700 is introduced onto disk substrates during polishing. As soon as the process in begun, the cleaning polish etch solution 700 is

introduced onto disk substrates via supply ports like supply port 525. Cleaning polish etch solution 700 is introduced onto disk substrates at a rate of 250 ml per minute. Cleaning polish etch solution 700 then depolymerizes (e.g., breaks silicon oxygen bonds in the case of an aluminosilicate glass disk substrate) the surface of the disk substrates (not shown) located in disk substrate carrier 600 and/or the attached slurry particles. As cleaning polish etch solution 700 depolymerizes the disk substrate material and/or the attached slurry particles, it is (they are) removed from the disk substrate by the polishing action of the cleaning polish etch solution 700 and the polishing pads 510 and 515. Under the above process parameters, the processing time is less than or equal to 10 minutes plus rinse for aluminosilicate glass disk substrates (less than or equal to 4 minutes plus rinse for Sendust head wafers). Near the end of the process, rinse water should be introduced onto the disk substrates to start cleaning polish etch solution 700 removal off the disk substrate. Too short of a rinse time adds cleaning load to the downstream cleaning process. In the preferred embodiment, a deionized (DI) rinse at a rate of 10 liters per minute for 2 minutes is used. The rinse preferably occurs at half the normal rpm rate, i.e., lower polishing plate 505 and attached polishing pad 515 should be set to rotate at 15 RPM, while upper polishing plate 500 and attached polishing pad 510 should be set to rotate at 30 RPM.

Soap-Based Cleaning Process

After coming off the polisher, the disk substrates 400 are subjected to a conventional soap-based cleaning process. For example, the disk substrates 400 may be ultrasonically cleaned with soap and/or mechanically scrubbed (Oliver scrub cleaning) using soap and a pad. (After coming off the polisher, head wafers are likewise subjected to a conventional soap-based cleaning process. For example, Sendust head wafers may be cleaned using a standard nonionic soap clean with pH in the 5 to 9 range with polyvinyl alcohol (PVA) pads in a wafer cleaner.) When used in conjunction with a conventional slurry without subsequent treatment using the cleaning polish etch composition and process of the present invention, such conventional soap-based cleaning processes leave residual slurry material that must be removed from the surface of the disk substrates by a further cleaning mechanism (i.e., etching or micropolishing). However, when used in conjunction with a conventional slurry and subsequent treatment using the cleaning

polish etch solution 700, such conventional soap-based cleaning processes completely remove the slurry material leaving the surface of the disk substrates 400 free from contamination. An example of a suitable conventional soap-based cleaning process for aluminosilicate glass disk substrates is set forth in Table 2 below.

TABLE 2

Step #	Cleaning Process for Superfinished Disk Substrates
1.	Place substrate in receiving tray/holding tub used to unload substrate off polisher (no more than 4 hrs.). Receiving tray/holding tub contains 0.2% Corsheen 9192LF available from Coral Chemical Co., Paramount CA + 0.1% H_2O_2 in deionized (DI) water at room temperature (RT).
2.	Subject substrate to 40 kHz ultrasonics (US) with 2.5% Corsheen 9192LF + 0.05 % H_2O_2 in DI water for 5 min. at 63 C.
3.	Place substrate in holding tub (no more than 4 hrs.). Holding tub contains 0.2% Corsheen 9192LF + 0.1% H_2O_2 in DI water at RT.
4.	Subject substrate to 7 sec. Oliver scrub with 2.5% Corsheen 9192LF + 0.05 % H_2O_2 in DI water at RT.
5.	Place substrate in holding tub (no more than 4 hrs.). Holding tub contains 0.2% Corsheen 9192LF + 0.1% H_2O_2 in DI water at RT.
6.	Places substrate in SpeedFam Neptune Cleaner available from SpeedFam Corp.: • Input conveyer with 0.2% Corsheen 9192LF + 0.1% H_2O_2 in DI water at RT; • First US cleaning tank with 0.2% Corsheen 9192LF + 0.1% H_2O_2 in DI water at 53 C for 3.5 min.; • DI rinse for 2 min.; • Polyvinyl alcohol (PVA) scrub with (pH 10.5) KOH + 0.05% H_2O_2 in DI water for 12-14 sec. at RT; • 3 DI rinses, each for 3.5 min.; • 37 % isopropyl alcohol (IPA)/DI US clean and spin dry for 3.5 min.

Subsequent Processing

After being cleaned, the disk substrates 400 may be further processed and finished by any other means known to those of skill in the art. After cleaning, for example, the disk substrates 400 may be sputtered with a series of layers, e.g., a magnetic layer and a carbon protection layer, using any of the various techniques that are conventional in the art. (After being cleaned the head wafers may be further processed and finished by any other means known to those of skill in the art. After cleaning, for example, a Sendust head wafer may be cut using conventional fabrication steps to provide a plurality of transducer heads 27 using any of the various techniques that are conventional in the art.)

Composition of Cleaning Polish Etch Solution 700

Etching Agents and pH

The chemical polishing portion of this chemical-mechanical process is achieved through the use of an etching agent. If disk substrate 400 is glass, for example, metal etchant such as Ce, Zr, Ti, Fe, Sn, Al, Cr, Ni, Mn and Zn ions may be used as the etching agent to depolymerize (break silicon oxygen bonds) the surface of disk substrate 400 and/or the attached slurry particles. Acid or base etchant solutions (without metal etchant) may be used as the etchant in lieu of metal etchant. In this case, metal ions from the substrate composition will be present in cleaning polish etch solution 700 for the cleaning polish etch process. It should be understood, however, that the particular etching agent used varies with the type of substrate involved. Preferably, Ce^{+4} and/or Fe^{+3} ions are used as the etching agent if disk substrate 400 is glass. The Ce^{+4} ions may be provided from cerium sulfate tetrahydrate ($Ce(SO_4)_2$ $4H_2O$), for example. The Fe^{+3} ions may be provided from ferric chloride hexahydrate ($FeCl_3$ $6H_2O$) and/or ferric sulfate nonahydrate ($Fe_2(SO_4)_3$ $9H_2O$), for example.

In addition, the pH of cleaning polish etch solution 700 is typically adjusted to be acidic by adding acid or basic by adding caustic agent. For example, if disk substrate is aluminosilicate glass the preferable pH range is pH 0 to 4; more preferably pH 0.8 to 3.0; and most preferably pH 1.0 to 2.0. It should be understood, however, that the preferable pH range is dependent on the

specific substrate. In fact, for glass substrates in general, it may be desirable to make cleaning polish etch solution 700 anywhere within the pH range of pH 0 to 12 depending on the glass. For example, a pH that for the substrate may be around or higher in pH than its isoelectric point. Stock removal rate generally goes down with increases in pH on aluminosilicate glass substrates until silica dissolution becomes significant around pH 11-12.

If disk substrate 400 is glass, for example, acids such as sulfamic (H_3NSO_3), nitric (HNO_3) and sulfuric acid (H_2SO_4) may be used to adjust the pH to be acidic. It should be understood, however, that the particular acid or caustic agent used varies with the type of substrate involved. Useful acids generally include inorganic acids such as nitric acid, nitrous acid, sulfuric acid, sulfurous acid, sulfamic acid, phosphoric acid, pyrophosphoric acid, phosphorous acid, perchloric acid, hydrochloric acid, chlorous acid, hypochlorous acid, carbonic acid, chromic acid, hydrofluoric acid; as well as organic acids such as formic acid and citric acid. Useful caustic agents generally include inorganic bases such as lithium hydroxide, sodium hydroxide, potassium hydroxide, calcium hydroxide, and ammonium hydroxide.

It should be understood that the present invention is not limited to a particular etching agent, a particular acid/caustic agent, or a particular substrate type. Additionally, it should be understood that there will be an optimum pH value that varies depending upon the particular combination of substrate type and etching agent. When cleaning polish etch 700 comes into contact with the surface of disk substrate 400, it reacts with the substrate and depolymerizes the surface and/or the attached slurry particles such that it (they) can be easily removed in combination with mechanical action.

Colloidal slurries, such as colloidal silica, are used on many different metal and alloy surfaces (e.g., Sendust, Permalloy, and the like) to polish to a smooth finish. Silica colloid, just as when used to polish glass, will bond to the surface oxides of metals leaving a silica contaminated surface. Using the cleaning polish etch mechanism of the present invention on other materials polished by colloidal silica, where silica is not present or not the main component

of the substrate, of the substrate, such as Sendust (Fe, Si & Al) used in head wafers, requires additional considerations. The etchant ions to choose from are still the same (e.g., Ce, Zr, Ti, Fe, Sn, Al, Cr, Ni, Mn and Zn ions) but the selection of the best etchant ion depends on the corrosion stable pH range of the substrate (which for Sendust is at pH 6 to 10), the anion effects on corrosion and which ion if left from the cleaning polish etch at very low concentrations could pose a problem. For Sendust head wafers, this results in iron and/or aluminum being the preferred ion. Alternatively, acid or base etchant solutions (without metal etchant) may be used as the etchant in lieu of metal etchant. Such acid or base etchant solutions include the useful acids and caustic agents listed above with respect to pH adjustment.

Examples

Example 1. Cleaning Polish Etch of Colloidal Silica on Glass Disk Substrate:

A solution was made by dissolving 12.4 g of cerium sulfate tetrahydrate ($Ce(SO_4)_2\ 4H_2O$) in a solution of 35 ml of 50 % sulfuric acid (H_2SO_4) plus 65 ml deionized (DI) water by heating to 90-100 C until dissolved. This solution was then diluted to 5 liters total volume by adding DI water with stirring to form the cleaning polish etch solution. The final pH of the cleaning polish etch solution was pH 1.14.

The cleaning polish etch solution was used to clean 95 mm aluminosilicate glass disk substrates, which were previously superfinished using a conventional colloidal silica slurry. The disk substrates to be cleaned were placed on a three motor, 9B-5P SpeedFam Double-Sided Polishing Machine made by SpeedFam Corporation. The disk substrates were held in carriers between Fujibo Napcon 4600 polishing pads made by Fujibo while pressure was applied axially and the polishing plates were rotated in opposite directions. The pressure applied was set to approximately 0.25 psi-disk (pounds per square inch of disk area). The lower polishing plate and the attached polishing pad were set to rotate at 30 RPM, while the upper polishing plate and the attached polishing pad were set to rotate at 60 RPM. The cleaning polish etch solution was introduced onto the disk substrates at a rate of 250 ml per minute. This process was performed

for 10 minutes, followed by 2 minutes of deionized (DI) water rinse at half the rpm rate at 10 liters per minute.

After coming off the polishing machine, the disk substrates were subjected to the conventional soap-based cleaning process set forth in Table 2 above. The conventional soap-based cleaning process completely removed the slurry material leaving the surfaces of the disk substrates free from contamination as seen by AFM. The average surface roughness of the disk substrate surfaces of this example was less than 2 Å with no asperities from slurry particles, AFM R_p (maximum individual peak height) less than 2 nanometers. This contrasts with the slurry particle asperities left from conventional superfinish slurry followed by conventional soap-based cleaning which are at a minimum the size of the superfinish slurry colloidal particle used, typically 7-70 nm. Initially, the reference disk substrates were identical to those used in this example, i.e., 95 mm aluminosilicate glass disk substrates previously superfinished using the same conventional colloidal silica slurry, pad and process conditions.

Example 2. Cleaning Polish Etch of Colloidal Silica on Sendust Head Wafer:

A solution was made by dissolving 2.78 g of ferrous sulfate hepahydrate ($FeSO_4$ $7H_2O$) in a solution of 50 ml of deionized (DI) water, then by adding 1.1 g of 30 % hydrogen peroxide mixed in 5 ml of DI water. This solution was then diluted to 2 liters while adjusting the pH to 10.5 using potassium hydroxide. After setting 48 hours at room temperature (RT), this diluted solution was further diluted to 8 liters (0.00125 molar) while adjusting the pH to 9.5 to 10.0 with potassium hydroxide (pH drifts towards neutral during the 48 hours).

The cleaning polish etch solution was used to clean Sendust head wafers, which were previously superfinished using a conventional colloidal silica wafer superfinishing slurry. The Sendust head wafers to be cleaned were placed on a three motor, 9B-5P SpeedFam Double-Sided Polishing Machine made by SpeedFam Corporation. The Sendust head wafers were held in carriers between Fujibo Napcon 4600 polishing pads made by Fujibo while pressure was applied axially and the polishing plates were rotated in opposite directions. The pressure applied was set

to approximately 0.25 psi-wafer (pounds per square inch of wafer area). The lower polishing plate and the attached polishing pad were set to rotate at 30 RPM, while the upper polishing plate and the attached polishing pad were set to rotate at 60 RPM. The cleaning polish etch solution was introduced onto the Sendust head wafers at a rate of 250 ml per minute. This process was performed for 4 minutes, followed by 2 minutes of deionized (DI) water rinse at half the rpm rate at 10 liters per minute.

After coming off the polishing machine, the Sendust head wafers were subjected to the a standard nonionic soap-based cleaning process with pH in the 5 to 9 range and polyvinyl alcohol (PVA) pads in a wafer cleaner. The standard nonionic soap-based cleaning process completely removed the slurry material leaving the surfaces of the Sendust head wafers free from contamination as seen by AFM. Without the cleaning polish etch mechanism of this example, the same standard nonionic soap-based cleaning process did not completely removed the slurry materials, i.e., contamination remained on the surfaces of the Sendust head wafers as seen by AFM just as with the glass substrates.

Consequently, the cleaning polish etch composition and process of the present invention can provide a substrate (e.g., a disk substrate, head disk wafer, etc.) having superior surface uniformity. In the case of a disk substrate, a significant decrease in flyheight can be achieved due to the highly uniform, glide defect free surface provided by the cleaning polish etch. In turn, the decreased flyheight can advantageously result in increased transducer readback sensitivity and increased areal density.

Moreover, contamination from the colloidal slurry is completely removed from the surface of the substrate by the cleaning polish etch composition and process of the present invention and subsequent conventional soap-based cleaning processes, without an additional etching or micropolishing. Unlike the cleaning techniques of etching or micropolishing, the cleaning polish etch mechanism provided by the present invention does not adversely alter the superfinish of the substrate or its surface stability to corrosion.

These traits make the present invention an attractive solution to keenly felt needs in the data storage device manufacturing industry.

While this invention has been described with respect to the preferred and alternative embodiments, it will be understood by those skilled in the art that various changes in detail may be made therein without departing from the spirit, scope, and teaching of the invention. For example, the invention may also be utilized in other data storage medium applications, such as in optical storage medium applications. Additionally, the invention may be utilized in applications other than data storage device applications, such as in semiconductor fabrication applications, lens fabrication applications, mirror fabrication applications or other applications that involve superfinishing a substrate. Accordingly, the herein disclosed invention is to be limited only as specified in the following claims.

What is claimed is: